Bloch-Front Turbulence in a Periodically Forced Belousov-Zhabotinsky Reaction

Aric Hagberg, T-7

Spatio-temporal disorder in extended systems commonly involves the spontaneous creation and annihilation of localized structures such as defects and vortices. The driving forces for the nucleation of defects and vortices are instabilities of periodic patterns or fronts. Defects in periodic patterns often result from the Benjamin-Feir-Newell instability, while spiral-vortex nucleation in bistable systems has been related to a front instability—the Nonequilibrium Ising-Bloch bifurcation.

We have demonstrated, in a periodically forced oscillatory Belousov-Zhabotinsky reaction and in mathematical models, a mechanism for creating spatio-temporal disorder. The mechanism consists of the creation of spiral vortex pairs through a transverse instability of fronts in the vicinity of a nonequilibrium Ising-Bloch bifurcation. This is the first direct experimental evidence tying front instabilities to vortex nucleation and disorder.

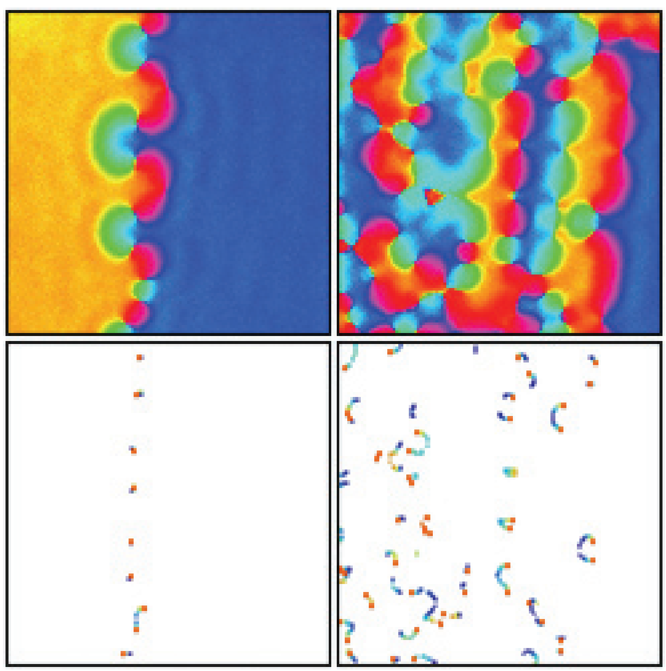

Fig. 1. Experiments on a periodically forced Belousov-Zhabotinsky chemical reaction show front break-up into a state of spatio-temporal disorder involving continual events of spiral-vortex nucleation and destruction. The initial front of the oscillation phase is unstable to transverse perturbations and vortices form in pairs along the front line. The bottom frames show the position of the vortices, the core location of the spiral wave, as red dots with colored tails indicating the motion and direction of travel.

We used an amplitude equation model, the forced complex Ginzburg-Landau equation, to reproduce the experimental observations with numerical solutions, and further described the mechanism for vortex creation with the normal form equations for a curved front line.

The normal form equations reduce the two-dimensional problem to the study of a one-dimensional set of equations for the curvature and velocity of the interface. With these equations we can capture the physics of a spiral-vortex nucleation event.

For more information contact Aric Hagberg at hagberg@lanl.gov.

[1] Bradley Marts, et al., *Phys. Rev. Lett.* **93**, 108305 (2004).

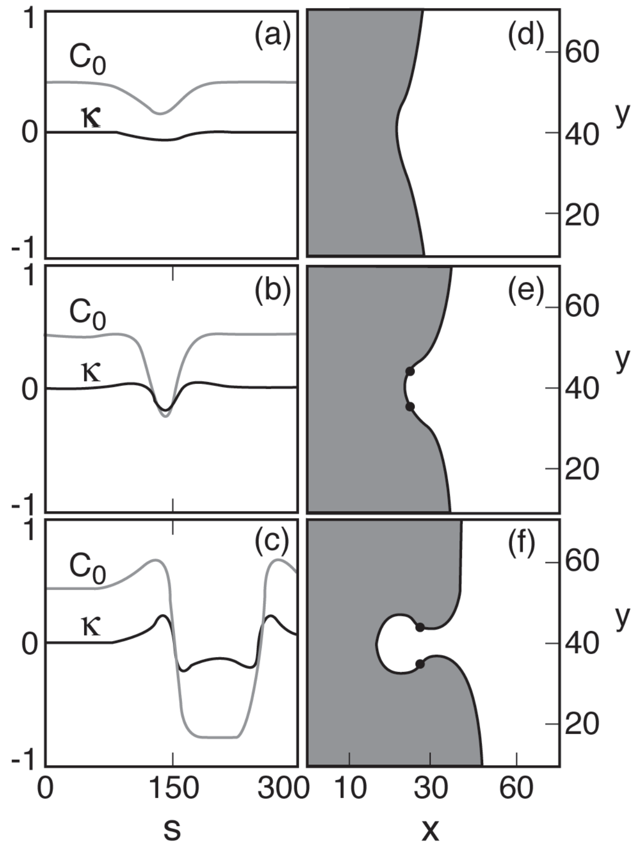

Fig. 2. *Nucleation of a single spiral-vortex pair in the front-line equations. Frames (a)–(c) show the front velocity C_0 and curvature k vs the arclength s. Frames (d)–(f) are the corresponding representation in the laboratory coordinate frame. A small perturbation in the curvature grows and a portion of the domain reverses direction causing spiral-vortex pair to nucleate along the front line.*